Skoltech
Skolkovo Institute of Science and Technology

# Jury Member Report – Doctor of Philosophy thesis.

**Name of Candidate:** Javier Antonio Ramirez Benavides

**PhD Program:** Materials Science and Engineering

**Title of Thesis:** Advanced single-walled carbon nanotube membranes for optoelectromechanical applications

**Supervisor**: Professor Albert Nasibulin

**Co-supervisor**: Assistant Professor Dmitry Krasnikov

**Name of the Reviewer: Dr. Sci. Stanislav Evlashin**

| | |
|---|---|
| I confirm the absence of any conflict of interest<br><br>Confirm | **Date: 05-11-2024** |

| |
|---|
| *The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.*<br><br>*If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.* |
| **Reviewer's Report** |
| *The thesis describes the production and study of the properties of free-standing carbon nanotube membranes. The first chapter provides a review of the literature on the properties, synthesis methods, functionalization techniques, and applications of carbon nanotubes, particularly their use as protection against aerosol particles in EUV lithography. The second chapter is devoted to experimental methods, detailing the techniques employed in the thesis. The third chapter presents the results obtained, while the fourth chapter contains the conclusions. A significant observation regarding the sections and overall work is that the readability could be improved; more time was needed to create a clearer structure for the dissertation. The topic of the dissertation, "ADVANCED SINGLE-WALLED CARBON NANOTUBE MEMBRANES FOR OPTOELECTROMECHANICAL APPLICATIONS," is quite broad, and the specified sections align well with its content. The chosen methods are appropriate for describing the results. The findings are on par with global standards and have been published in highly regarded journals, indicating their significance.* |

*Questions to be Addressed:*

1. *I would like to know about the stability of the structures under EUV radiation over an extended period. What is the service life of different membranes under this type of radiation?*
2. *Why do Sn and In not penetrate through the membrane during annealing?*
3. *How do films degrade with fluence at EUV? Given that EUV radiation is quite energetic, it should lead to rapid degradation not only of nanotubes but also of other carbon materials. I would also like to see data on changes in mechanical characteristics due to fluence. Please provide relevant literature.*
4. *The work studies the properties of structures under EUV conditions; however, the characterization of optical properties is provided only for the visible range. Have studies been conducted with EUV on welded tubes? How did the use of $HAuCl_4$ affect absorption in wavelengths shorter than 100 nm?*
5. *Is it appropriate to conduct mechanical tests on bundles and compare them with films after the modification?*
6. *Is there a rearrangement of nanotubes during welding, or does an amorphous layer grow without rearranging nanotubes in the contact zone? It would be beneficial to perform XPS analysis to determine sp3 and sp2 carbon content depending on the welding mode. What does the literature indicate regarding this?*

**Provisional Recommendation**

☒ *I recommend that the candidate should defend the thesis by means of a formal thesis defense*

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*